vidual MRAs) of which radiation properties, such as maximum beam directions and sense of polarizations, can be changed. In other words, the element factor is not fixed and has variable properties. This degree of freedom may translate into higher array gain, polarization reconfigurability, and beam-tilt capability not only in y-z plane but also in x-z plane. Also, the scan loss inherit to standard array may be alleviated for the MRAA, when the beam is steered in the x-z plane.

FIG. **14** illustrates beam-steering capabilities of an exemplary MRAA **1400** consistent with embodiments disclosed herein. For steering in the x-z plane, the radiation pattern of the MRAA **1400** may not be related to the array factor as it does not take effect in the x-z plane. The beam steering in this plane may be accomplished by the beam-steering capabilities of the individual MRAs of the MRAA **1400**. Irrespective of the beam-steering angle, there may be little phase difference from element to element ($\Delta\alpha=k_0 d \sin\theta_0=0$) and accordingly, the phase front may stay parallel to the y-axis along which the array elements are arranged as illustrated.

In certain embodiments, when the modes of operation of the individual MRAs of the MRAA **1400** correspond to the beam-steering modes ($\theta_{xz}=30°$, 0° and −30°), with either linear and circular polarizations, in the x-z plane, the realized gain pattern of the MRAA **1400**, $G_T(\theta)$, in this plane may be expressed as the summation of the realized gain patterns of individual MRAs, as presented below in Equation 16:

$$G_T(\theta)=\Sigma_n G_{en}(\theta)\ (n=0\ldots 3)\ (x\text{–}z\text{ plane}) \tag{16}$$

where $G_{en}(\theta)$ represents the imbedded realized gain pattern of the individual n^{th} MRA element in the x-z plane. The term "imbedded" may indicate that an individual gain pattern is obtained when the corresponding MRA is excited, while the other MRAs are terminated with matched loads. In this manner, the effects of mutual coupling among array elements are taken into account when calculating $G_{en}(\theta)$ for each individual radiator of the MRAA **1400**.

Under certain conditions, where the effects of mutual coupling are ignored, all elements of the MRAA **1400** may have the same or similar realized gain patterns $G_{en}(\theta)=G_e(\theta)$. Utilizing the principle of superposition given in Equation 15, the realized array gain may be expressed according to Equation 17, presented below:

$$G_T(\theta)=N\times G_{en}(\theta)(x\text{–}z\text{ plane}) \tag{17}$$

In certain embodiments, the working mechanism of the MRAA **1400** steering in the y-z plane may be similar to the working mechanism of a standard linear array. The additional degree of freedom provided by the variable radiation properties of the individual MRA elements of the MRAA **1400** combined with the array factor in the y-z plane may enhance the MRAA **1400** performance as compared to that of a standard array.

FIG. **15** illustrates further beam-steering capabilities of a MRAA **1400** array consistent with embodiments disclosed herein. When the MRAA **1400** performs beam steering in the y-z plane, the individual MRA elements may be set to operate in the beam-steering modes in the y-z plane with beam steering angles of $\theta_{yz}=-30°$ and 30. Under these circumstances, the realized gain pattern of the MRAA **1400** can be expressed according to Equation (18), presented below:

$$G_T(\theta)=G_e(\theta)\times N|F_a(\theta)|^2(y\text{–}z\text{ plane}) \tag{18}$$

where $F_a(\theta)$ is the normalized array factor, N is the number of elements, and $G_e(\theta)$ represents the realized gain pattern of an individual MRA in the y-z plane.

The general expression for the realized gain of the MRAA **1400** may be expressed according to Equation 19, presented below:

$$G(\theta,\varphi)=\frac{1\pi R^2}{P_{in}}S(\theta,\varphi) \tag{19}$$

where $S(\theta,\phi)$ is the radiated array power density at the far-field distance of R, and P_{in} represents the input power for the MRAA **1400**.

For a given beam direction, the MRAA **1400** can achieve polarization reconfigurability as its individual MRA elements can change the sense of polarization between linear and circular polarizations. Reconfigurability for the beam steering in x-z plane and the y-z plane may be performed by optimizing the pixel surface of the parasitic layer accordingly. Polarization reconfigurability may also be performed. For example, steering in other directions such as $\theta=\pm5°$, ±10°, ±15°, ±20°, etc., along with polarization reconfigurability both in the x-z and y-z planes may be performed by further optimizing the parasitic pixel surface using the methods disclosed herein.

It will be readily understood that the components of the disclosed embodiments, as generally described herein, could be arranged and designed in a wide variety of different configurations. For example, in certain embodiments, active driven antenna elements may also comprise liquid metal material and may be reconfigurable utilizing microfluidic techniques similar to the those described above. Similarly, in further embodiments, antenna elements (e.g., active or parasitic elements) may comprise an array of microfluidic reservoirs that may be reconfigured to vary the architecture of the antenna. Embodiments disclosed herein may be also incorporated in other suitable antenna architectures and designs. Accordingly, the above detailed description of the embodiments of the systems and methods of the disclosure is not intended to limit the scope of the disclosure, but is merely representative of possible embodiments of the disclosure. In addition, the steps of any disclosed method do not necessarily need to be executed in any specific order, or even sequentially, nor do the steps need be executed only once, unless otherwise specified.

Similarly, it should be appreciated that in the above description of embodiments, various features are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure. This method of disclosure, however, is not to be interpreted as reflecting an intention that any claim requires more features than those expressly recited in that claim. Rather, inventive aspects lie in a combination of fewer than all features of any single foregoing disclosed embodiment. It will be apparent to those having skill in the art that changes may be made to the details of the above-described embodiments without departing from the underlying principles set forth herein.

What is claimed is:

1. A reconfigurable antenna comprising:

an active driven antenna element configured to emit a field of electromagnetic energy; and

a parasitic element disposed over the active driven antenna element, the parasitic element being physically separated from the active driven antenna element, the parasitic element comprising an array of selectively reconfigurable pixels and a network of mechanical switches configured to selectively reconfigure the array of selectively reconfigurable pixels based on one or more applied control voltages by physically coupling a plurality of reconfigurable pixels of the array of selectively reconfigurable pixels, the parasitic element being configured to couple with the field of electromagnetic